OBSTACLE DETECTION

FOR

MOBILE ROBOT

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OBSTACLE DETECTION

FOR

MOBILE ROBOTS

Dissertation Submitted

to

the department of

Computer Science and Engineering

Of

National Institute of Technology, Rourkela

in partial fulfillment of the requirements

for the degree of

Bachelor in Technology

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Certificate

This is to certify that the work in the project entitled *Obstacle detection for a mobile robot* by *Pendyala Kavya* bearing roll number *111CS0445* is a record of her work carried out under my supervision and guidance in partial fulfillment of the requirements for the award of the degree of *Bachelor of Technology* in *Computer Science and Engineering.*

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Declaration

I hereby declare that all the work contained in this report is my own work unless otherwise acknowledged. Also, all of my work has not been previously submitted for any academic degree. All sources of quoted information have been acknowledged by means of appropriate references.

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Acknowledgment

I would like to thank my supervisor *Professor Ratnakar Dash* for his exemplary guidance, monitoring and for providing me with an open and free environment to learn things and implement them.
I convey my regards to all the faculty members of Department of Computer Science and Engineering, NIT Rourkela for their valuable guidance throughout my journey in NIT Rourkela. I would like to thank my friends for helping me out in times of necessity and being there for me always.
I would like to express my profound gratitude to my parents and sister for their support and blessings without which this task would not have been easier.

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Abstract

This project Obstacle detection and avoidance by a mobile robot deals with detection and avoidance of obstacles of a mobile robot. Webcam captures images of the environment in which the robot moves. Image processing methods are then performed to identify the existence of obstacles within the environment. Algorithms are implemented in MATLAB with Image Processing toolbox. Planar geometry and corner detection methods are used in this obstacle detection method.Digital camera takes the pairs of images of the scene. Using planar homography warped image is formed. Obstacle detection is done by comparing the warped image with the final image.

Keywords: Obstacle Detection, Mobile Robot, MATLAB.

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CHAPTER 1
INTRODUCTION

1 Introduction

Image processing is processing of images, for example, photos or feature outlines. The yield is the changed adaptation of the data image or an arrangement of attributes or parameters identified with the image. The computer evolution that has occurred throughout the most recent 20 years has given chances in the advancements in the field of advanced image processing. This has thus, opened up a huge number of applications in different fields, which could use technology.

1.1 Obstacle Detection

Obstacle detection is defined as "The determination of whether a given space is free of obstacles for safe travel by an autonomous vehicle" by Singh [11]. It is really very important for performing many other operations in mobile robots like navigation and avoidance.
A good obstacle detection system must be capable of the following [Singh]:

- To detect obstacles on a given space in good time
- To detect and identify correct obstacles
- To identify and ignore ground features that may appear as obstacles

Images of the real environment of the mobile robot are taken using a webcam and these images are processed in the computer that performs obstacle detection.

1.2 Overview of report structure

This thesis has five chapters:
Chapter 1 titled **INTRODUCTION** introduces the project. It gives us the objective of the project.

Chapter 2 titled **LITERATURE REVIEW** does all the background study necessary for the implementation of the project. It includes basics of Image Processing and Computer Vision, their brief history, their applications and how they are used in the project to achieve the objective of it.

Chapter 3 entitled **IMPLEMENTATION** it describes the sub-problems of the main problem i.e., obstacle detection, provides proper solution to each sub-problem. Implements the solution of the sub-problems and combines the result to give the whole result of obstacle detection.

Chapter 4 entitled **EVALUATION** explains the test plan initially. conducts wide range of tests. Best of the results are shown in this report.

Chapter 5 entitled **CONCLUSION** gives the summary of the other chapters and concludes the report.

CHAPTER 2

LITERATURE REVIEW

2 Literature Review

This chapter does all the back-ground study necessary to gain enough knowledge of topics like Image Processing Computer Vision to implement this project. Sub problems also like Corner Detection,Matching the corners, Computing Homography using RANSAC algorithm are also studied here

2.1 Computer Vision

Computer vision is one of the sub fields of artificial intelligence in the field of computer science. Computer Vision is just like machine imitating human vision. Since both forms of visions (Human vision and Computer Vision) are dependent on light radiated from the environment, Computer Scientists do no consider this to be an accurate one.

2.2 Corner Detection

Corners are distinguished by the huge variations of intensities in x and y directions. Corners detected while analyzing the images are used in various applications. Point correspondences are necessary to compute the homography of a scene. Corners are normally chosen since they are the points which are easily distinguished and will be easy to match them on other images.

Corner detection is done using intensity function I(x,y) of the pixels. The most used corner detection method is Harris corner detection methods. Here, in our project the corner detection algorithm written by KLT and Harris is used. In this method Local structure matrix of every pixel is found out. With this matrix of every pixel, it is found out whether the pixel is corner or not.

Local structure matrix(A) of a pixel(x,y) with intensity function I(x,y) is

$$A = \begin{pmatrix} (\frac{\partial I(x,y)}{\partial x})^2 & \frac{\partial I(x,y)}{\partial x}\frac{\partial I(x,y}{\partial y} \\ \frac{\partial I(x,y)}{\partial x}\frac{\partial I(x,y)}{\partial y} & (\frac{\partial I(x,y)}{\partial y})^2 \end{pmatrix}$$

In the event that there is noise in the image, it is smoothed by utilizing a gaussian channel w(r,s) with a preset s and a box filter before computing the local structure matrix of each pixel. Since A is symmetric, It has precisely 2 positive eigen values
This is the essential standard which is utilized as a part of Harris corner indicator [3] when we work with greyscale images. Algorithm for Harris Corner Detection method

- For each pixel (x, y) find A
- For each A find 2 eigenvalues λmax, λmin
- Sort all λmin, discard pixel with small λmin.
- Discard pixels with large λmax - λmin
- Remaining are corner points

2.3 Planar Homography

Planar homography is described as the relationship between corresponding points between two images of the same scene. It is used to identify points on the same

plane of an image. Obstacle detection via image warping could only be done with a homography of the scene. Hence computation of homography is necessary. For homography matrix of a particular plane of the scene, all the points on the image of a plane holds the same relationship.
Let X be the coordinates of a point on the image plane while X is the coordinates of that point on another plane.

$$[xyz]^T \approx P[x'y'0T] = P[XYZ]^T$$

2.3.1 Homography relationship of two different images of a plane

Given two images of a plane, if there is a homography between two images, then that relationship is known a planar homography. Then the relationship between that corresponding 2 points on the same plane(X and X are points in which are on different images).

$$X' = HX$$

Thus if H for a plane which is in between two images is known, If X is a point on first image, let us consider X is the corresponding point of X on second image. So X is computed only when X belongs to the same plane of the related homography. Similarly reverse can also be done using the following formula.

$$X = H^{-1}X'$$

2.4 Computation of Homography matrix

The computation of H becomes an OLS (ordinary least squares) problem if scale ambiguity of the homography

equation(h9=1) is used. This is the inhomogeneous solution to the computation of H.
From $X = HX$ Where $X = (st1)$ and $X = (xy1)$

$$H = \begin{pmatrix} h_1 & h_2 & h_3 \\ h_4 & h_5 & h_6 \\ h_7 & h_8 & h_9 \end{pmatrix}$$

We have

$$\begin{pmatrix} s \\ t \\ 1 \end{pmatrix} = H \begin{pmatrix} x \\ y \\ 1 \end{pmatrix} \begin{pmatrix} s \\ t \\ 1 \end{pmatrix} = \begin{pmatrix} xh_1 + yh_2 + h_3 \\ xh_4 + yh_5 + h_6 \\ xh_7 + yh_8 + 1 \end{pmatrix}$$

$s = xh1 + yh2 + h3$ equation i)

$t = xh_4 + yh_5 + h_6$ equation ii)

$1 = xh_7 + yh_8 + 1$ equation ii)

Multiplying equation i and equation iii we have

$s(xh_7 + yh_8 + 1) = (xh_1 + yh_2 + h_3)1$

$sxh_7 + syh_8 + s = xh_1 + yh_2 + h_3$

$-xh_1 + -yh_2 + -1h_3 + 0h_4 + 0h_5 + 0h_6 + sxh_7 + syh_8 = -s$

Multiplying equation ii and equation iii we have

$t(xh_7 + yh_8 + 1) = (xh_4 + yh_5 + h_6)$

$txh_7 + tyh_8 + t = xh_4 + yh_5 + h_6$

$0h_1 + 0h_2 + 0h_3 + -xh_4 + -yh_5 + -1h_6 + txh_7 + tyh_8 = -t$

The two equations would be like

$$\begin{pmatrix} -x & -y & -1 & 0 & 0 & 0 & s*x & s*y \\ 0 & 0 & 0 & -x & -y & 1 & t*x & t*y \end{pmatrix}$$

$$\begin{pmatrix} h_1 \\ \dots \\ h_8 \end{pmatrix} = \begin{pmatrix} -s \\ -t \end{pmatrix}$$

For n points it is like

$$\begin{pmatrix} -x_1 & -y_1 & -1 & 0 & 0 & 0 & s_1*x_1 & s_1*y_1 \\ 0 & 0 & 0 & -x_1 & -y_1 & 1 & t_1*x_1 & t_1*y_1 \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ -x_n & -y_n & -1 & 0 & 0 & 0 & s_n*x_n & s_n*y_n \\ 0 & 0 & 0 & -x_n & -y_n & 1 & t_n*x & t_n*y \end{pmatrix}$$

$$\begin{pmatrix} h_1 \\ h_2 \\ h_3 \\ h_4 \\ h_5 \\ h_6 \\ h_7 \\ h_8 \\ 1 \end{pmatrix} = \begin{pmatrix} -s_1 \\ -t_1 \\ \vdots \\ \vdots \\ s_n \\ t_n \end{pmatrix} \; tmp1 * htmp = tmp2$$

$$htmp = tmp1^{-1} * tmp2$$

$$H = \begin{pmatrix} htmp_1 & htmp_2 & htmp_3 \\ htmp_4 & htmp_5 & htmp_6 \\ htmp_7 & htmp_8 & 1 \end{pmatrix}$$

It would be ideal if you take note of that a satisfactory solution can't be acquired utilizing this system if h9 =

0, however, this is the system most generally utilized on account of the uncommonness of such circumstances. Four-point correspondences are necessary to solve the computation of H. However in the event that any three of these points are collinear the arrangement would not be acceptable. This is on account of the impact of having an arrangement of co-linear points in solving linear equations is the same as having a couple of points subsequent to either can characterize a straight line and neither one of the cans characterize a plane.
RANSAC method is used here for the computation of the homography of a scene.
RANSAC Algorithm

- RANSAC robust estimation: Repeat for N samples where N is determined adaptively
  - Select a random sample of 4 correspondences and compute the fundamental matrix H.
  - Calculate the distance d for each putative correspondence
  - Compute the number of inliers consistent with H by the number of correspondences for which d ¡ t pixels
- Choose the H with the largest number of inliers. In the case of ties choose the solution that has the lowest standard deviation of inliers.
- Non-linear estimation: re-estimate H from all correspondences classified as inliers by minimizing a cost function

2.5 Image Warping

Exactly when two pictures are taken of a scene from particular camera positions, the relationship X' = HX can be used to make a warped picture from the first picture. The warped picture is fundamentally an expected image of the second image if all images on two pictures lie on the same plane as the ones utilized as a part of computing homography of the scene. At the point when the warped picture is made, the warped coordinates are found by X' = HX. The intensity of X is imitated to position X' on the warped picture.

A few pixels on the warped picture may not be warped positions of any pixels of the first picture. A few pixels may be warped positions of more than one pixel of first image

Interpolation is utilized to tackle these issues.

blank pixels take the mean value of neighboring non-blank pixels.

Pixels that are warped positions for more than one pixel on the first picture take the normal intensities of all the relating pixels from the first image.

Expecting the plane to which homography has a place with is ground, the two pictures (the second picture and the warped picture) will be same except from the parts which don't fit in with the ground plane(here they are obstructions). The difference in the intensities of the corresponding pixels between the warped and second picture gives the obstacles in that environment. This is the strategy utilized as a part of this project of obstacle detection.

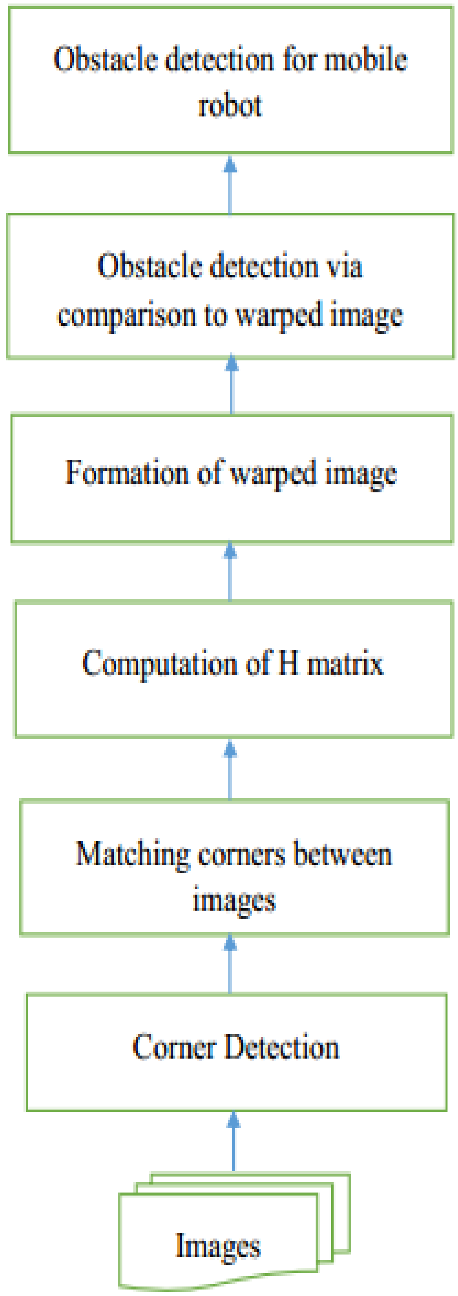
2.6 Summary of Review

This chapter has done enough background study to gain the basic knowledge of the topics which we use in this project like Image processing, Computer vision to give an efficient design and implementation of this project.

CHAPTER 3
IMPLEMENTATION

3 Implementation

3.1 Design plan



3.1.1 Design Methodology

The system is developed in bottom up approach. In this method, the main problem(Obstacle detection) is broken down into smaller sub-problems which are dealt individually whose solutions put together to give the solution to the final system.

3.1.2 Hardware Requirement

Device Specifications Personal Computer (HP GV6)

- Intel Core i3 CPU M370 @ 2.40 GHz Processor
- 3.00GB (2.86GB Usable) RAM

3.1.3 Software used

MATLAB Version R2012a with Image Processing Toolbox.

3.2 Description of sub problems

Here is the brief explanation of the objective and the implementation of the solutions of each and every module. For the methods which are included in the solutions where background knowledge is necessary, references to literature review have been included. Implementation and coding are done by myself in the mentioned development environment unless otherwise stated.

- **Corner Detection**: Two images(first image and final image) are processed into data in the development environment. Corners are identified on both the images. The Harris detector algorithm [3] developed by Peter Kovesi is used.

- **Matching corners between initial and final image**: Output from the Corner Detection module i.e., the coordinates of corners are taken as input in this module and here pairs of corresponding corners of both the images are found out. The output of this module is the set of coordinates of same corner on the first image and last image. Correspondences of points are selected from the set of points which has the most similar intensities of neighboring pixels with the one being matched.

- **Computation of Homography**: Here, the input is the output of the previous model i.e., matching the corners between the first and final images. Homography matrix for that scene is computed with the matched corners using RANSAC inhomogeneous method.

- **Warped image formation**: The input here is the homography matrix computed in the previous module Computation of homography matrix. It is used in the formation of warped image from first image. Expected positions of all pixels on the first image are found and their intensity values are copied to that expected positions. This forms the warped image.

- **Obstacle Detection via comparison to warped image**: The input here is the warped image formed in the previous module warped image formation. Two new images are formed here. One is the image formed by subtracting the intensity values of pixels of corresponding locations of the second image and warped image. The second image is formed by the difference in intensity values of blocks (16*16) of pixels of corresponding locations. These two images detects the obstacles.

3.3 Summary of implementation

This chapter gives the requirements of the project quite, discusses the sub-problems in the project and gives a design plan to solve the sub-problem. Design methodology, development environment and problem-solving methods in the chosen environment are discussed in great detail.

CHAPTER 4
EVALUATION

4 Evaluation

Evaluation is the most important part in any process of development of system. It helps to know if the objective of the image is achieved. Its operations are investigated using wide range of experiments. Implementation of tests and results obtained in those tests are discussed here, with a brief summary.

4.1 The Test Plan

The objective of this project is to detect the obstacles in the path of a mobile robot. The method used here is Obstacle detection via comparing final image to warped image which depends on how accurately the homography matrix is computed. Homography matrix's accuracy in turn depends on finding point correspondences on the ground plane. Same value of H is not obtained every time when it is computed using RANSAC algorithm. Some are inaccurate. Best of all results is shown in the figures.

4.2 Results of corner detection

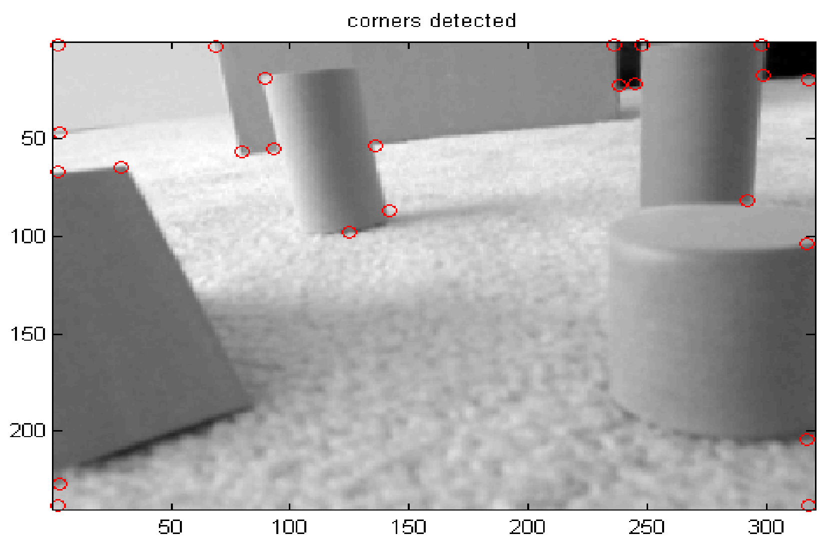


Figure 1: Results of corners detected

4.3 Result of matching corners

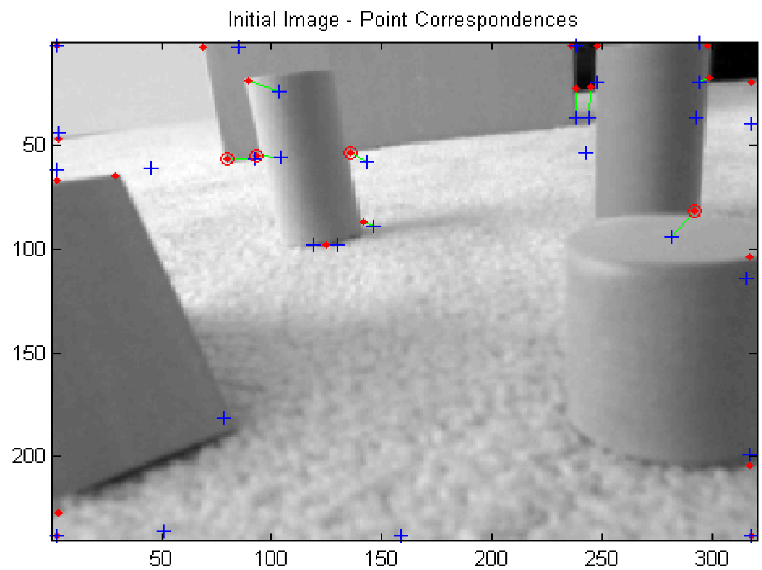


Figure 2: Result of matching corners on first image

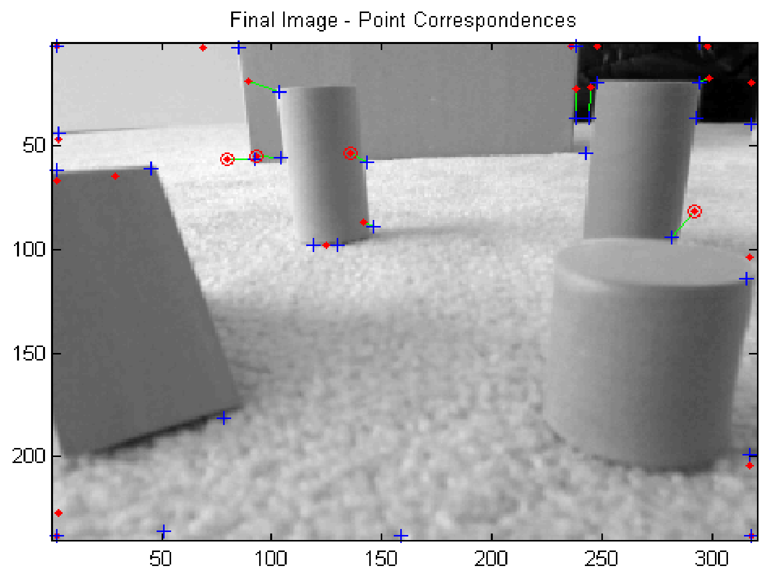


Figure 3: Result of matching corners on second image.

4.4 Warped Image

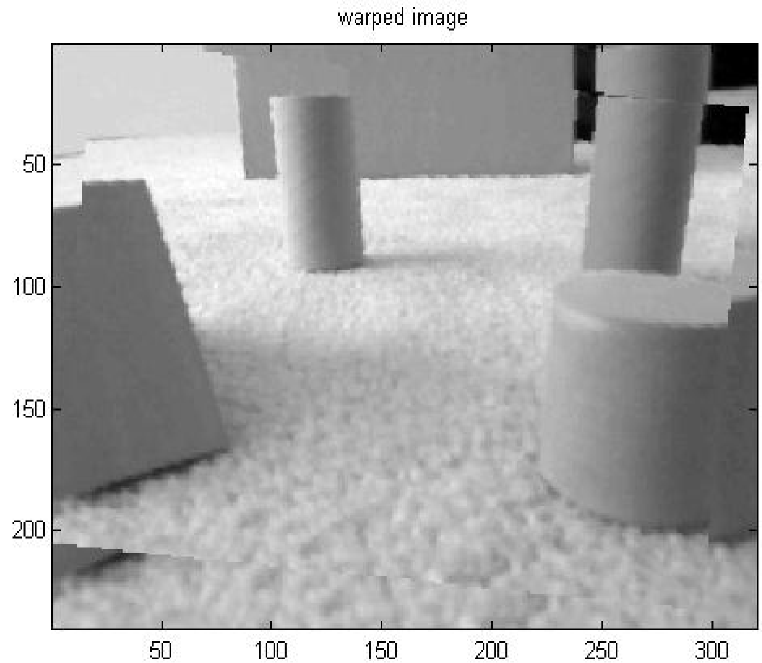


Figure 4: Warped image

4.5 Difference between warped and final image

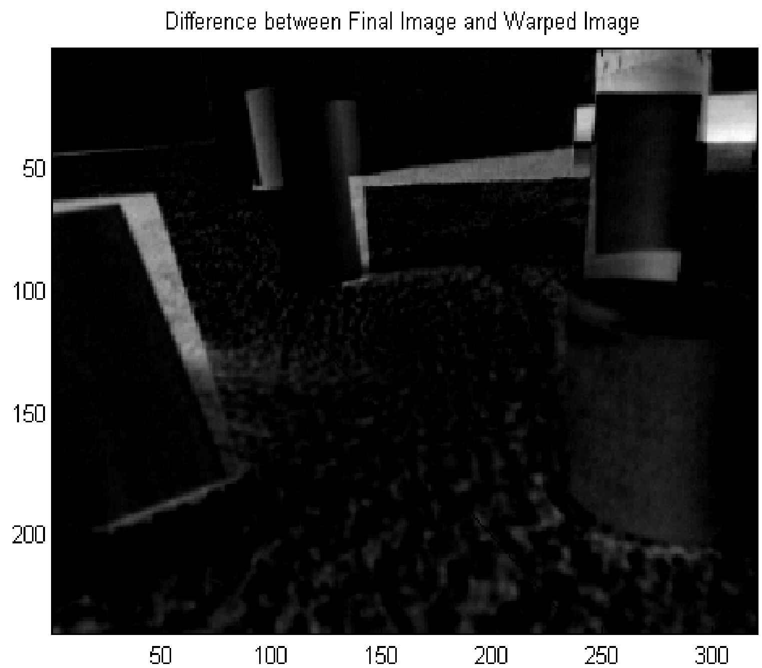


Figure 5: Difference between warped and final image

4.6 Obstacle Detection

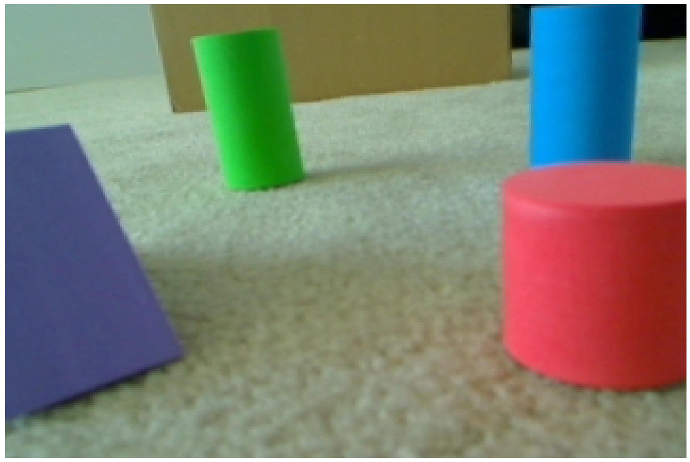


Figure 6: Initial image

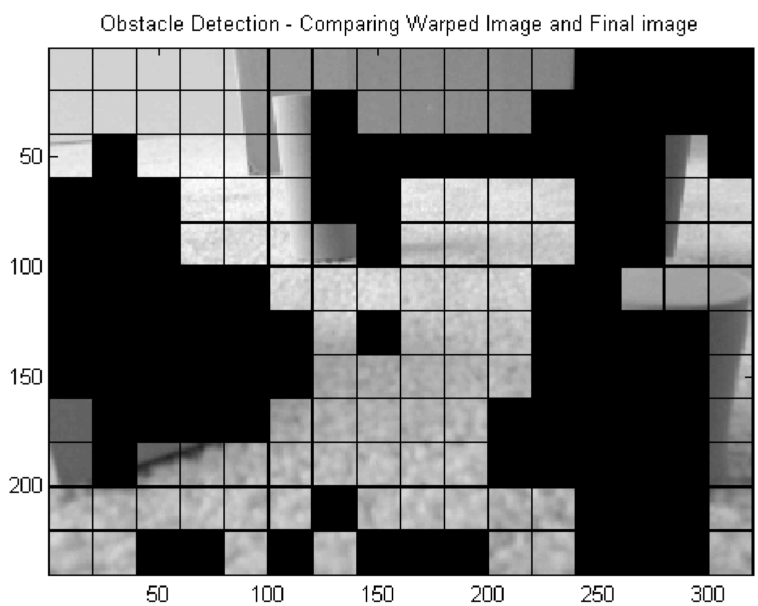


Figure 7: Obstacle detection via comparing warped image and second image. Original Image

4.7 Summary of this chapter

Wide range of tests are being conducted to evaluate the solution and implementation of the solution of the sub-problems(Corner detection, image warping). The best of all results obtained during these tests are provided.

CHAPTER 5
CONCLUSION

5 Conclusion

This chapter gives brief summaries of previous chapter and suggests possible future work.

5.1 Overall Summary

Chapter 1 Introduction introduces the project, Objective of the project i.e., Obstacle detection and discusses its applications in robotics

Chapter 2 Literature Review, has done enough background study to gain the basic knowledge of the topics which we use in this project like Image processing, Computer vision to give an efficient design and implementation of this project.

In Chapter 3 Implementation gives the requirements of the project quite, discusses the sub-problems in the project and gives a design plan to solve the sub-problem. Design methodology, development environment and problem-solving methods in the chosen environment are discussed in great detail.

In Chapter 4 Evaluation,Wide range of tests are being conducted to evaluate the solution and implementation of the solution of the sub-problems(Corner detection, image warping). The best of all results obtained during these tests are provided.

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